DOCUMENT RESUME

ED 230 442 SE 042 068

AUTHOR Loase, John F.; Monahan, Brian D.
TITLE The Relationship Between Academic Requirements and Job Requirements in Computer Science.
PUB DATE 83
NOTE 28p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *College Mathematics; Competence; *Computer Science; *Educational Background; *Education Work Relationship; Employment Level; Higher Education; *Job Performance; Job Training; *Mathematics; Mathematics Education
IDENTIFIERS Mathematics Education Research

ABSTRACT

This study explored the relationship between mathematical competency (mathematics training received in college) and mathematics computer specialists use on the job. The study was developed based upon an hypothesis that many computer occupations have formal academic requirements for admission and advancement which have an unclear relationship to the actual demands of the job. A survey instrument (included with this report) was mailed to 240 computer scientists at three different employment levels: level 1-- employees carrying out orders of supervisors who have little/no role in long-term research and day-to-day decision-making; level 2-- middle management supervisors; and level 3-- researchers developing procedures for the future and performing, with minimum supervision, the most creative activities within the occupation. Completed surveys used in analyses included: level 1 (N=24); level 2 (N=29); and level 3 (N=41). Results indicated that coursework taken and the frequency with which the mathematical topics were used were not significantly different for the different levels of practitioners. Results also indicated that although completion of courses in mathematical topics beyond elementary arithmetic serves as one of the most significant factors for job entry and advancement, those topics are rarely used by the majority of computer professionals. (JN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
✓ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

ED230442

THE RELATIONSHIP BETWEEN ACADEMIC REQUIREMENTS AND JOB REQUIREMENTS IN COMPUTER SCIENCE

by

John F. Loase
Yonkers High School
The State University of New York at Purchase

and

Brian D. Monahan
Longfellow Middle School
Iona College

Mailing Address
Brian D. Monahan
14 Deerfoot Lane
Dobbs Ferry, NY 10522

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Brian D. Monahan
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Running Head: The Relationship

SE049060

The Relationship Between Academic Requirements and Job Requirements in Computer Science

Abstract

The study used a survey instrument to describe the academic preparation in mathematics of three levels of computer professionals and to describe the mathematical topics which those professionals use on the job. The results indicated that the coursework taken and the frequency with which the mathematical topics were used were not significantyl different for the different levels of practitioners. The results also indicated that although completion of courses in mathematical topics beyond elementary arithmetic serves as one of the most significant factors for job entry and advancement, those topics are rarely used by the majority of computer professionals.

The Relationship Between Academic Requirements and Job Requirements in Computer Science

Need for the Study

In scrutinizing the 1981 Occupational Outlook Handbook, one cannot fail to recognize a strong positive connection between mathematical requirements in educational pre-requisites for occupational entry and the concomitant demand and remuneration of such employment. Electrical engineering, computer science, actuarial work, and chemistry exemplify occupations which usually require considerable mathematical preparation at the collegiate level and correspondingly pay well. Additionally, these occupations represent professions in which demand exceeds supply. Mathematical competency appears to be a significant factor in determining one's occupational choices.

Very little research has been completed characterized by an intensive analysis of the mathematical competencies requisite for effective job functioning in specific occupations.

Preliminary Review of Related Literature

Laws (1968) and Miller (1970) interviewed occupational representatives in technical areas and 44 occupational specializations in science. Both studies challenged the mathematical collegiate pre-requisites expected of the practitioner; Laws and Miller recommended a re-evaluation

of pure mathematics requirements for employment. Saunders (1978) interviewed a single representative from each of 100 occupations and found that facility with whole numbers, decimals, use of calculators, and percentage as essential. Saunders' sample needs to be increased in order to obtain more reliable results. Hayman (1978), Dawes and Jesson (1979), and Swadener (1979) explored the mathematical needs of the non-professional and independently found that global generalizations were not possible regarding industrial mathematical needs.

Within the domain of computer science, several attempts have been made to develop curriculum specifications for the collegiate preparation of the computer practitioner. Curriculum '68 required the completion of introductory calculus, mathematical analysis I, linear algebra, introduction to discrete structures, numerical analysis, plus two of the following: mathematical analysis II, advanced multivariate calculus, algebraic structures, or probability and statistics.

The curriculum was modified in 1978 and numerical analysis was deleted along with the two elective mandates. Both curricula emphasized traditional calculus-based continuous mathematics. A significant question that emerges from examination of the traditional curriculum is the relationship between continuous mathematics and real-world applications. To phrase the question

differently: are most of the real-world applications of computer science continuous or discrete in nature and solution?

Ralston and Shaw (1980), two professors of computer science, inquired into the relationship between the commercial needs of the computer scientist and the standard collegiate mathematics curriculum for a computer science degree. Although Ralston and Shaw did not interview practitioners in order to assess the mathematical needs of the computer scientist firsthand, they made strong criticisms of (in their view) "arbitrary and needlessly rigid mathematical pre-requisites" for the degree of computer science at the bachelor's level. Ralston and Shaw questioned the relevance of Curriculum '78 which recommended a sequence of elementary calculus, intermediate calculus, linear algebra, and calculus-based probability and statistics as required mathematics courses for the degree of computer science. While Ralston and Shaw did not argue for less mathematics, they did present a case for a different kind of mathematics. If Ralston and Shaw have correctly assessed the industrial mathematical needs of the computer scientist, then many types of mathematics have been serving as inappropriate obstacles which stop many aspiring computer professionals from pursuing a degree in computer science.

The Subjects

The subjects were two hundred forty computer scientists who were selected from several the membership list of the Asscіation for Computing Machinery. Those included:

1. Subscribers to professional journals
2. Personnel officers of computer concerns
3. Placement data from colleges in the tri-state area.

The professionals were limited to those practitioners from New York, New Jersey, and Connecticut.

Purpose of the Study

The purpose of this study was to build upon the research of Ralston and Shaw (1980) and explore the relationship between mathematical competency and occupational suitability in computer science. In computer science, many workers currently have little in the way of collegiate credentials, but a degree in computer science, with its advanced mathematical sequence, is a guarantee of a secure job and a promising career. The computer science practitioners, not the hiring officials, need to be consulted regarding the mathematical needs of the employee. Many research studies have relied exclusively upon interviews with management officials in order to ascertain the appropriateness of salient mathematical topics.

Studies such as Koopida's (1980) give evidence that there is frequently a discrepancy between employer and employee perceptions of formal mathematical requisites for satisfactory job functioning. The purpose of the current study was to investigater relationships between the mathematical training that computer professionals receive in college and the mathematics that those professionals actually use on the job.

The study was developed based upon a hypothesis that many computer occupations have formal academic requirements for admission and advancement which, at best, have an unclear relationship to the actual demands of the job. This inquiry will attempt to begin to clarify this relationship.

Procedures of the Study

Computer science was not selected arbitrarily as the focus of this inquiry. It emerged from a computer search which selected professions which require mathematical competency well beyond elementary arithmetic. Subdivisions of occupational categories in computer science were created based upon responsibility and sophistication of duties. Those subdivisions appear below:

Level I - The employee who carries out the orders of the supervisor at level II but who has little or no role in the long term research or day to day decision making.

Level II - The middle management supervisor who is in

touch with corporate headquarters needs and who assigns and supervises general practitioners.

Level III - The researcher who is developing procedures for the future and who is typically performing, with minimum supervision, the most creative activities within the occupation.

A sample of 240 computer scientists who are members of the Association for Computing machinery was chosen for the study. Respondents were asked to list the duties of their jobs in as detailed and specific a way as possible; this led to the categorizations of the professional into one of the three partitions mentioned above. The survey instrument appears in Figure 1:

Figure 1

Survey of Mathematical Training
of Computer Science Professionals

What is your job title?_____

Please list the duties of your job in as detailed and specific a way as possible.

_____

_____

_____

Identical checklists were developed of 69 salient mathematical competencies paired with ratings of frequency and importance. A combined version of the list, accompanied by the directions for deciding on frequency and importance, appears in Figure 2.

Figure 2

Frequency and Importance of 69 Topics

1 = Not important	N = Never
2 = Slightly important	Y = Once per year
3 = Important	M = Once per month
4 = Very important	W = Once per week
5 = Essential	D = Once per day
	H = Several times per day

Mathematical Topcis

1 Operations with Whole Numbs. +,-,x,÷

2 Operations with Decimals +,-,x,÷

3 Percentage

4 Fractions +,-,x,÷

5 Ratio - Proportion

6 Area, Perimeter

7 Operations with Negative Numbers +,-,x,÷

8 Operations, Order of

9 Word Problems

10 Linear Equations

11 Solving Quadratic Equations

12 Graphing

13 Simultaneous Equations

14 Factoring

15 Quadratic Formula

16 Binomial Theorem

17 Exponential Functions

18 Logarithms

Figure 2 (Continued)

19 Sine, Cosine, Tangent

20 Complex Numbers

21 Trigonometric Interpolation

22 Trigonometric Identities

23 Law of Sines

24 Law of Cosines

25 Trigonometric Functions, Secant, Cosecant

26 Limits

27 Derivatives

28 Continuity

29 Integration

30 Algebraic and Transcendental Functions

31 Chain Rule

32 Solid Analytic Geometry

33 Vectors

34 Partial Differentiation

35 Partial Integration

36 Multiple Integrals

37 Infinite Series

38 Theory of Differentiation

39 Theory of Integration

40 Theory of Limits

41 Theory of Continuity

42 Theory of Uniform Convergence

43 Interpolation Using Numerical Methods and Classical Polynomial Formulas

44 Differentiation by Computer Method

45 Integration by Numerical Methods

46 Numerical Solution of Linear Equations

47 Numerical Solution of Non-Linear Equations

48 Numerical Solution of Ordinary Differential Equations

Figure 2 (continued)

49 Algebraic and Topological Aspects of the Real Number Line

50 Lebesque Measure Theory on the Real Number Line

51 Basic Theorems in Probability

52 Random Variables

53 Distribution Functions

54 Expected Value

55 Binomial, Poisson, Normal Distributions

56 Sampling Distributions

57 Point Estimation

58 Interval Estimation

59 Testing Statistical Hypotheses

60 Simple Regression

61 Simple Correlation

62 Analysis of Variance

63 Multiple Regression

64 Experimental Design

65 Stochastic Processes

66 Non-Parametric Hypothesis Testing

67 Sequential Tests of Hypotheses

68 Decision Theory

69 Multivariate Analysis

Also a check list ascertaining formal mathematical preparation of the professionals was created. That list appears in Figure 3.

Mathematical Training

HIGH SCHOOL	_____	(1)	General Mathematics
	_____	(2)	Algebra I
	_____	(3)	Algebra II
	_____	(4)	Trigonometry
	_____	(5)	Elementary Calculus
UNDERGRADUATE	_____	(6)	Elementary Calculus
	_____	(7)	Calculus I
	_____	(8)	Calculus II
	_____	(9)	Numerical Analysis - Calculus Based
	_____	(10)	Probability and Statistics I - Calculus Based
	_____	(11)	Probability and Statistics II - Calculus Based
	_____	(12)	Real Analysis
	_____	(13)	Earned Bachelor's Degree in Mathematics
MASTERS	_____	(14)	Advanced Calculus
	_____	(15)	Numerical Methods - Calculus Based
	_____	(16)	Probability and Statistics I - Calculus Based
	_____	(17)	Probability and Statistics II - Calculus Based
	_____	(18)	Earned Masters Degree in Mathematics
DOCTORATE	_____	(19)	Real Analysis
	_____	(20)	Numerical Analysis - Calculus Based
	_____	(21)	Probability and Statistics - Calculus Based
	_____	(22)	Earned Doctorate in Mathematics

The three instruments were pilot-tested prior to the mailing of the final instruments. The surveys proved to be efficient (eleven minute average completion time) and no need to modify the instruments was evidenced.

Three separate statistical procedures were used in order to explore the research question. Percentage of agreement of raters was used to check the reliability of the developed trichotomies within the occupation. Median scores for frequency and importance together with the semi-interquartile range measure were complemented by the computation of a correlation coefficient between median frequency and median importance for the 69 topics. Finally the number of courses completed (x-variable) and the number of topics used several times per week, daily or weekly (y-variable) were counted. Two separate one-way anaylses of variance and four linear correlation coefficients were used to test the research question, namely, if there is a significant relationship between mathematics used on the job and formal mathematical training.

Results

Response Rate

A sample of 240 computer scientists were mailed a copy of the survey instrument. The first mailing of the instrument resulted in a response rate of twenty-six percent. A second mailing to the professionals resulted in a fourteen percent increase in the final response rate to

forty percent. Eleven surveys were returned incomplete and were not included in the statistical analysis of the results.

Reliability Analysis

In order to establish the reliability of the three distinct categories within the domain of computer science, a college professor of computer science and a professor of mathematical statistics were asked to rate the practitioners at level one, two or three based upon the respondents' description of job duties. The reliability was based upon percentage of agreement and ranged from ninety-two to one hundred percent.

Frequency-Importance Correlation

A linear correlation coefficient of .95 was computed between frequency and importance measures. Since frequency and importance of the 69 salient mathematical topics were so highly related, it was thought unwarranted to consider both measures in the statistical analyses. As a result, frequency was retained as the independent variable and importance was not considered in the following analyses.

Coursework-Frequency Analysis

The means and standard deviations of the number of courses taken and the frequency with mathematical topics are used are reported in Table 1. To quantify the mathematics used on the job, the authors counted for each practitioner the number of topics used several times per

day, weekly of monthly.

TABLE 1

MEANS AND STANDARD DEVIATION

	MEAN	STANDARD DEVIATION	N
Number of Courses Taken			
Level I	7.54	1.88	24
Level II	9.10	3.38	29
Level III	8.56	2.85	41
Number of Topics Used at Least Weekly			
Level I	8.33	6.30	24
Level II	11.90	9.53	29
Level III	13.56	12.30	41

In order to test the null hypothesis that the sample means of coursework and frequency of topic were equal withing the three levels of computer practitioners, two anaylses of variance ($p<.05$) were performed. Both yielded F ratios that were not statistically significant. The results of the analysis of variance are reported in Table 2.

TABLE 2

ANALYSIS OF VARIANCE FOR MEAN

FREQUENCY AND MEAN COURSEWORK

	Degrees Freedom	Mean Square	F
Number of Courses Taken	2	12	1.4
	91	8.7	
Number of Courses	2	207.83	2.12
Used at Least Weekly	91	98..	

The preceding table indicates that there were nostatistically significant difference in the mathematics used or mathematics taken by the various levels of practitioners.

Correlation Between Coursework and Frequency

In order to analyze the relationship between completed mathematical coursework and the number of matematical

topics used at least weekly, four linear correlation coefficients were computed. The results are presented in Table 3. A t-test with n-2 degrees of freedom was used to test significance. In three of the four correlations within the computer science domain, the t-test indicated significant results.

TABLE 3

CORRELATION BETWEEN COURSEWORK AND FREQUENCY OF TOPICS

LEVELS	CORRELATION
Low	r = -.21
Manager	*r = .37
High	*r = .45
Overall	*r = .36

Finally, the frequency with which the 69 mathematical topics, ranging in sophistication from arithmetic to highly complex topics, were tabulate. The results are reprted in Table 4.

TABLE 4
SURVEY RESULTS (FREQUENCY)
COMPUTER SPECIALISTS OVERALL

Topics	Frequency (%) 0	1	2	3	4	5	Median	Q
1	2	4	4	9	13	67	4.8	.5
2	3	4	7	17	14	54	4.6	1.0
3	8	6	11	20	23	32	3.7	1.1
4	7	8	11	19	19	37	3.8	1.2
5	11	10	17	17	20	26	3.2	1.4
6	47	22	12	12	6	1	.7	.9
7	16	6	6	13	16	44	4.1	1.3
8	19	9	8	11	19	34	3.7	1.7
9	28	7	13	17	13	22	2.6	2.0
10	38	12	23	14	8	4	1.5	1.1
11	48	22	23	4	1	1	.6	.7
12	26	9	27	21	10	8	2.1	1.4
13	44	21	21	8	4	1	.8	.9
14	46	16	24	8	7	0	.8	.9
15	54	22	16	6	2	0	.4	.7
16	51	27	18	1	3	0	.5	.6
17	41	22	18	9	8	2	.9	1.0
18	46	16	19	10	9	1	.8	1.0
19	61	13	13	8	4	0	.3	.7
20	69	13	10	4	2	1	.2	.4
21	71	16	9	3	1	0	.2	.2
22	68	19	8	4	1	0	.2	.3
23	68	24	6	1	1	0	.2	.3
24	68	24	4	2	1	0	.2	.3
25	71	22	4	1	1	0	.2	.3
26	59	19	12	2	8	0	.3	.6
27	60	19	11	3	7	0	.3	.6
28	66	21	6	3	4	0	.3	.4
29	62	22	6	3	7	0	.3	.4

TABLE 4 - Continued

Topics	Frequency (%) 0	1	2	3	4	5	Median	Q
30	63	17	10	3	7	0	.3	.5
31	72	11	10	6	1	0	.2	.3
32	77	10	10	2	0	1	.2	.2
33	54	14	13	9	6	3	.4	.9
34	68	18	9	3	2	0	.2	.4
35	73	17	7	3	0	0	.2	.3
36	72	19	6	2	1	0	.2	.3
37	63	16	11	7	2	1	.3	.6
38	77	20	2	1	0	0	.2	.2
39	78	20	1	1	0	0	.1	.2
40	74	21	1	3	0	0	.2	.2
41	81	13	2	3	0	0	.1	.2
42	83	13	0	2	1	0	.1	.2
43	58	26	10	4	1	1	.4	.5
44	67	19	11	1	2	0	.3	.4
45	69	18	9	2	2	0	.2	.4
46	60	18	12	6	3	1	.3	.6
47	68	21	9	1	0	1	.2	.3
48	77	14	7	2	0	0	.2	.2
49	84	11	2	1	1	0	.1	.2
50	91	7	1	1	0	0	.0	.2
51	40	19	19	16	7	0	1.0	1.0
52	46	13	21	10	7	3	.8	.9
53	48	13	19	12	4	3	.7	1.0
54	46	18	16	12	7	2	.8	1.0
55	44	16	17	14	6	3	.9	1.0
56	43	19	19	11	4	3	.9	.9
57	59	14	13	8	3	2	.3	.7
58	60	13	13	7	4	2	.3	.7
59	49	20	16	10	2	3	.6	.9

TABLE 4 - Continued

Topics	Frequency (%) 0	1	2	3	4	5	Median	Q
60	52	22	14	6	2	3	.5	.7
61	46	28	17	6	1	3	.7	.6
62	46	24	21	4	2	2	.7	.7
63	53	19	17	7	2	2	.4	.8
64	54	19	13	8	3	2	.4	.7
65	61	22	8	3	3	2	.3	.5
66	71	16	3	6	2	2	.2	.3
67	73	12	6	4	3	1	.2	.3
68	60	19	9	6	6	1	.3	.6
69	70	12	9	4	2	2	.2	.3

Survey Frequency Data (Overall)

Several salient findings emerged from scrutiny of the data as presented in Table 4.

(1) Beyond elementary arithmetic four of 62 topics had median use more frequent than once per year by the computer specialists.

(2) Above elementary arithmetic three of 62 topics had median use more frequent than once a month.

(3) Beyond elementary algebra one of 54 topics had more frequent median use than once a year.

(4) Six of seven topics from elementary arithmetic had daily or weekly use by the majority of computer specialists.

Analysis of Frequency Data Within Categories I, II, III

The results of the frequency of topics used for each of the participants in the study is too voluminous to report here. In lieu of a complete presentation of the data, the following summary is offered.

Elementary arithmetic had greater than weekly median use for five of seven topics for practitioners from levels one and two; for computer specialists in the creative domain six of seven topics from elementary arithmetic were used weekly by the majority of the respondents. Beyond elementary arithmetic three of 62 topics from Level I, (12 of 62 - Level II, 14 of 62 - Level III) had median use

greater than annual. Beyond elementary algebra zero of 54 topics were used more frequently than once a month by Level I practitioners; identical statistics emerged from Level II and Level III specialists. Seven of 62 topics for Level II and four of 62 topics (Level III) were reported to have more than annual median frequency within the computer science occupational domain.

Discussion

For the computer specialists, coursework and frequency of use of certain mathematical topics were not significantly different from level to level. It appeared that the occupation was not differentiating occupational assignments by means of formally completed coursework although such coursework was one of the primary avenues for job entry and advancement.

For the Level I practitioners there was no significant relationship between completed coursework and mathematical demands of the job. All correlations but for the Level I practitioner proved significant. There was a statistically significant relationship between course and mathematical needs for the computer scientists overall. For the Level I practitioner, however, a negative correlation coefficient emerged between mathematical training and mathematics used on the job. This finding is particularly significant in that it suggests a need for a separate curriculum for the level I and level III computer science practitioner. All

but the correlation coefficient for the Level III practitioners was low. Perhaps the low correlations were attributable to the restricted variability which was a consequence of the divisions that were created in developing the trichotomy. This trichotomy was essential in order to address the enormous variation of job duties within such occupations.

An analysis of the median frequency of use of selected mathematical topics yielded the following conclusions:

(1) Elementary arithmetic is used daily by most practitioners of computer science.

(2) Topics from elementary algebra occur frequently on the job but their frequency of need overall is less than that of arithmetic topics.

(3) The vast majority of topics beyond elementary algebra are rarely used by the majority of computer professionals in spite of the fact that their satisfactory mastery at the collegiate or examination level is one of the most significant factors related to job entry or advancement.

(4) Above elementary algebra over ninety-five percent of the topics from collegiate mathematics are used less frequently than monthly. There is a considerable disproportion between the typical formal mathematical preparation of the mathematical professional and the mathematics regularly used on the job.

Recommendations

The preceding results should be made available to employers of computer professionals. Additional correlations studying the relationship between certain courses such as calculus and probability and mathematical frequency should be computed from this data.

Also, a nation-wide study of a similar nature should be undertaken in an attempt to determine if the preceding results are generalizeable nation-wide. A study in which computer scientists are rated by their supervisors and this rating correlated with their quantified mathematical competency would be profitable since mathematical competency is one of the primary avenues for job entry and advancement in computer science. If the results of this study are found to be generalizeable nation-wide, then a separate curriculum for the level I practitioner and level III practitioner should be developed at the collegiate level.

Also, psychological factors such as concept generation and concept transformation should be considered in their relationship to job functioning in the mathematical professions. Perhaps, mathematical competency is simply a guarantor of high level intellectual functioning, (i.e. concept generation) which correlates highly with job functioning. Since mathematical competency requires a good memory, attention to detail, and an ability to deal with

abstract concepts, perhaps it is a valid means of screening for the computer science domain. On the other hand, if closer analysis and scrutiny of the role of mathematics indicates that its primary purpose is screening, then perhaps alternate methods of demonstrating job aptitude may be introduced. It is clear that mathematical competency is frequently necessary to keep abreast of new developments in computer science, particularly in intelligently reviewing the research literature.

Hopefully, this research will provide the germ of intensive and in-depth research investigating the formal collegiate requirements for satisfactory job functioning. Since there currently exists a nation-wide shortage of computer professionals, the two year colleges and technical institutes would profit immediately by substantive needs analyses of the formal course offerings requisite to the effective job functioning of the computer professional.

It is clear from the survey results that computer professionals possess far more mathematics in their formal background than the typical job regularly demands. However, in answering one question we have raised a host of deeper questions that will require years of intensive research to satisfactorily address.

REFERENCES

Dawes, W. G. & Jesson, D. Is there a basis for specifying the mathematical requirements of the 16 year old entering employment. International Journal of Mathematical Education in Science and Technology, 1979, 10, 391-400.

Hayman, M. A survey of job opportunities and job requirements and their effect on the matematics teaching for early leavers in secondary school. Journal of Mathematical Education and Science, 1978, 3, 147-155.

Laws, N. Mathematical expectations of technicans in Michigan industries. Michigan State Department of Public Instruction, Lansing, 1968.

Miller, G. H. What mathematics courses should a mining engineer take. Transactions of the Society of Mining Engineers of AIME, 1970, 247, 53-54.

Ralson, A. & Shaw, M. Curriculum '78 -- Is computer science really that unmathematical. Communications of the ACM, 1980, 23,

Saunders, H. When are we ever gonna have to use this. Mathematics Teacher, 1980, 73, 7-16.

Swadener, M. What mathematical skills hiring officials want. Mathematics Teacher, 1979, 72, 444-447.